AUTOMATED MICROWAVE LOW POWER TESTING TECHNIQUES FOR NLC

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Abstract

As part of the Next Linear Collider (NLC) collaboration, the NLC structures group at Fermilab has started an R&D program to fabricate NLC accelerator structures in cooperation with commercial companies in order to prepare for mass production of RF structures. To build the Next Linear Collider, thousands accelerator structures containing a million cells are needed. Our primary goal is to explore the feasibility of making these structures in an industrial environment. On the other hand the structure mass production requires "industrialized" microwave quality control techniques to characterize these structures at different stages of production as efficiently as possible. We developed several automated set-ups based on different RF techniques that are mutually complementary address this problem.

1 INTRODUCTION

In any particular design for 500 GeV center–of-mass, the NLC would consist of 10,000 to 20,000 accelerator structures. Each structure consists of about 50 to 100 of accelerating cells and the total number of cells manufactured with very tight tolerances comes to about one million [1]. Due to these tight tolerance requirements, quality control (QC) of RF parts is one of critical steps for this program. The full scope of QC includes many topics such as single cell and full structure QC, RF and mechanical QC, etc [2].

At Fermilab, we have been developing QC set-ups exploring different microwave techniques to insure that the machined cells are within the design tolerances, and finally, to confirm overall RF performance of the completed structure. Keeping in mind mass production demands we tried to make our set-ups fast, completely automated with data processing in real time. Also we tried to reduce the number of mechanical manipulations with parts and complete structures as much as possible. The ultimate goal was to make QC procedures simple enough so that technicians can do it. This goal is not achieved in full yet and probably final QC and tuning of complete structure will still be a job for RF engineers.

The structures we have produced so far are not the final NLC design, but they are various structures to support R&D on the breakdown problem [3]. So, we had to design the mechanical part of set-ups flexible enough to meet different structure designs. This requirement didn't allow us to make full automation of the mechanical part of set-ups, which is especially desired for the single cell QC set-up. This automation will be developed after the final design of the structure is finished.

2 SINGLE CELL QC

To verify the accuracy of the machining of cell parts, we do so-called "single cell microwave QC". The particular design of our single cell QC set-up has been determined by several considerations

1) The cells are machined in the form of "caps" to allow room for tuning holes. So, we need an additional half-cell to measure the frequencies of "0"-like and "π"-like modes.
2) It is almost definite that in the final NLC structures, the diameter of each cell (2b), the thickness of its iris (t), and the diameter of its aperture (2a), all vary progressively from cell to cell. This is done to detune the dipole modes and prevent short-range cumulative build up of wake-fields, while maintaining quasi-constant gradient characteristics of the fundamental accelerating mode [1].
3) The structures are nested, so the choice of contact measurements has been rather natural. Besides, the non-contact approach has some disadvantages [4] we wanted to avoid at this stage of R&D.

The "cup" shape of cell parts and tapering of structures has resulted in an immediate loss of the possibility to perform direct absolute frequency measurements. We have to make a large number of very fine simulations of set-up, prepare and verify master caps for comparison, and perform measurements of short stacks every time we get a different cell design in order to avoid possible systematic errors.

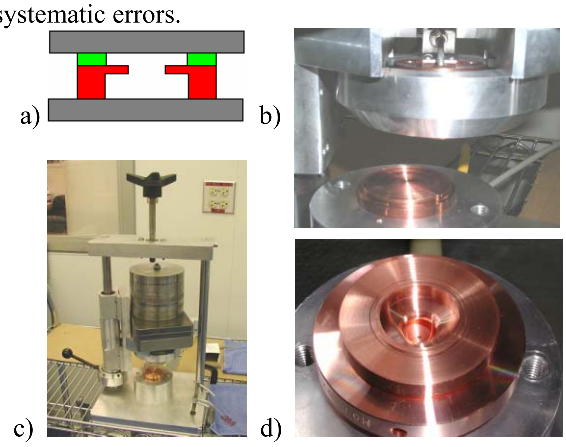

Fig.1. a) Schematic view. b) Bottom block and upper floating block. c) General view of set-up. d) Cup and half-cell installed on bottom block.

Basically, the set-up consists of two flat ground blocks with a cup and a half-cell in between them. We decided to use a replaceable half-cell part despite the additional contact surface in order to facilitate the use of different half-cells for different cup designs. The ground blocks have offset antennas axes which permit the measurement of both the fundamental modes and the HOM frequencies. Figure 1 shows schematic, central parts and general views of the set-up.

During measurements our network analyzer is operated and controlled by a PC, or more precisely, by a program written in LabView. After next cup is loaded and an operator has pushed a button, the program scans a pre-determined interval of frequencies, then locates and measures resonant frequencies and quality factors of modes. The program has a simple and convenient interface (see Fig.2) that permits the online control of all parameters being measured and saves the result as a file, which can be opened by Excel.

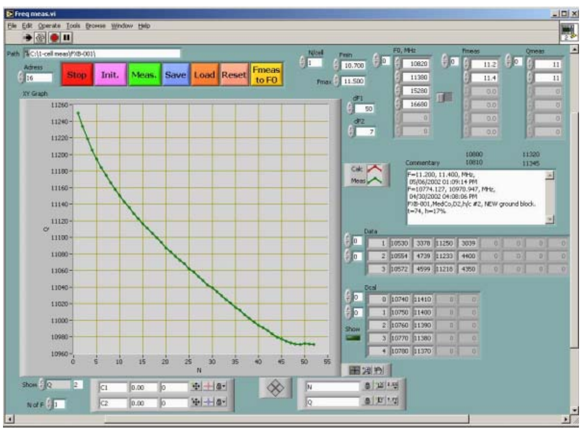

Fig.2. The window of LabView program for single cell QC.

We have achieved an accuracy ± 0.2 MHz (random errors) for frequency measurements and ±3% for Q-factor measurements. One cup can be measured (four modes) in 35 seconds, but the necessity of careful handling and visual inspection of cups increases this record time to 1-1.5 minutes per cup.

We made a valuable checking of the system's simplicity and reliability. A summer student with minimal instruction spent 45 minutes getting the feel of the testing machine by repeatedly testing the same sample cup. This is the only practice he had before spending three hours testing a full set of 52 cups alone. Except for the additional time spent, the results were identical to that obtained by a qualified RF engineer.

3 PLUNGER SET-UP

A two-plunger set-up is used to measure cell frequencies in stacks of cups. Two plungers (antennas) isolate a cell or number of cells in a stack and the frequencies of different cells and modes can be measured. A brazed stack is placed on movable platform and an actuator (linear motor) controlled by LabView moves it

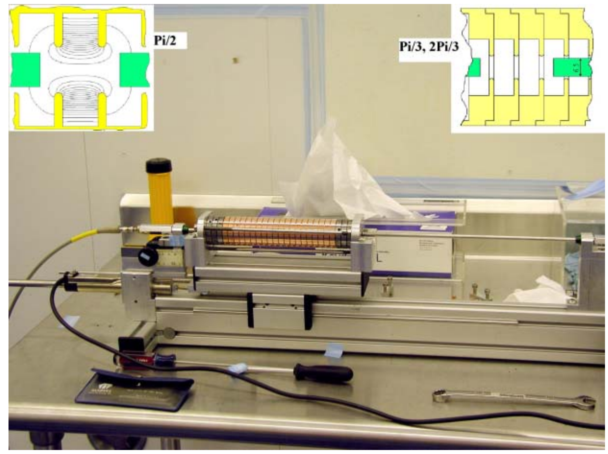

Fig.3. The plunger set-up.

along the plungers and data from the analyzer is recorded (Fig.3). The plungers are in air and do not contact the irises. Precise positioning of the stack relative to the gap between plungers is determined by the data analysis. While the measurements are normally automated, the operator has also many options for manual control via LabView interface.

The advantage of this set-up is the possibility to measure HOM frequencies which cannot be seen easily thru the end cells because of HOM detuning and structure tapering.

The disadvantages of the plunger set-up are obvious – sag and vibration of antennas preclude the measurement of long structures and pose a threat of damage to the irises. Thus, we use it primarily for R&D purposes.

Using this set-up we also perform traditional nodal measurements of complete structures (Fig.4).

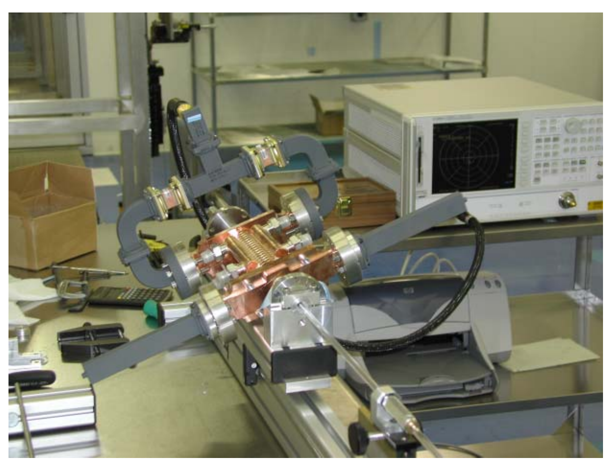

Fig.4. The plunger set-up for nodal measurements.

4 BEAD-PULL SET-UP

We check and tune completed accelerating structures using an automated bead-pull system. The technique implemented is based on traveling wave perturbation [5]. The details of our collecting and processing the reflection coefficient data (S_{11}) from the network analyzer are described in [6]. Figure 5 shows the general arrangement of our bead-pull system.

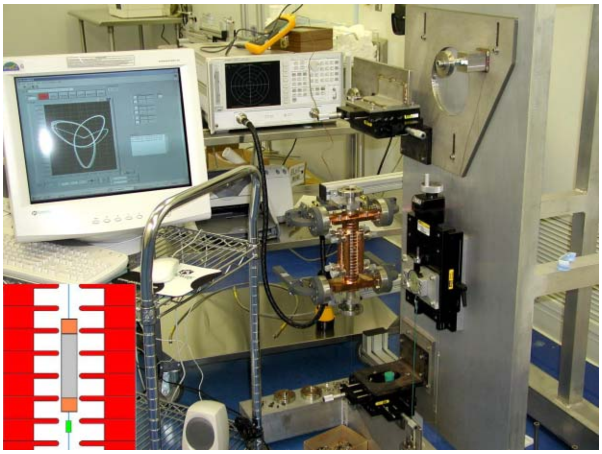

Fig.5. The general arrangement of the bead-pull set-up.

In order to reduce the total number of test set-ups, we decided to combine our bead-pull and plunger measurement. In the first case, a small metallic cylindrical bead is attached to a thin nylon string along the axis of the vertically mounted accelerator structure and the usual bead-pull measurements can be accomplished. For nodal shift measurements we designed a light, short plastic plunger with metal tips. This plunger is mounted on the same string as the bead, thus the only manipulation required to switch a type of measurement is to drive the string until plunger enters the structure under test.

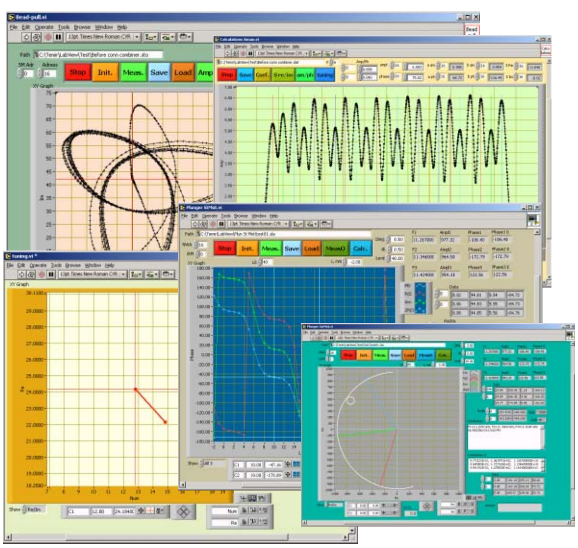

Fig.6. The windows of LabView program for bead-pull measurements and complete structure tuning

A LabView program controls a stepping motor and network analyzer and processes the data on-line. The results of measurements and calculations can be displayed in various forms (Fig.6). The most important feature of the software is the capability for on-line tuning of a structure: an operator uses calculated recommendations and sees immediate results of tuning.

We expended significant effort to simplify the mechanical design of the set-up and to make the apparatus as easy to use as possible in order to expedite the work in Clean Room environment while wearing gloves and masks.

5 CONCLUSION

As part of the NLC collaboration, we have contributed to the development of an RF laboratory, including system hardware, software, and associated automatic measurement techniques. Due to the high accuracy requirements associated with the RF measurements and tuning for X-band components and assembled structures, this development process has been very challenging. We consider the present status of our RF lab as a good prototype which meets some mass-production demands such as automation of RF measurements, developed software based on common approach to all RF measurements, and a unified electronic file system convenient for database development. From this point of view, the single cell set-up is close to being useful as a "red-green light" device in an industrial environment.

On the other hand, the mechanical parts of our equipment still have room for significant improvement. Our near term goals are automated disk loading with pressure control, direct temperature control, or with the use of master cells, etc. Some innovative ideas in RF measurement and tuning techniques could also help to turn RF test set-ups into RF measurement machines.

6 REFERENCES

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